Overview

- BIOS and “the platform”
- Why do we want to test it?
- History of BITS
- Tour of existing functionality
- Fun with scripting in a ring 0, pre-OS environment
Minimal support needed to boot an OS
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- Platform configuration
- Interface to platform functionality
The “Platform”

- CPUs
- Chipset
- Memory
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- Memory
- Minimal video
- Minimal input

Non-standard stuff: lights, buttons, bells, whistles

Josh Triplett and Burt Triplett

BITS: BIOS Implementation Test Suite
The “Platform”

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- Non-standard stuff: lights, buttons, bells, whistles
Platform configuration

- Highly configurable hardware
- Powers on in a minimal safe configuration
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- Programming CPU and chipset registers
- Tuning for optimal configuration
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- Programming CPU and chipset registers
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- Enabling technologies that require additional configuration
Interface to platform functionality

- 16-bit interrupts
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- ACPI: Advanced Configuration and Platform Interface
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- Data structures describing standard components
Interface to platform functionality

- 16-bit interrupts
- ACPI: Advanced Configuration and Platform Interface
- Some data structures describing standard components
- Mostly, bytecode methods to interpret and execute
BIOS has gotten pretty complicated

- Thousands of pages of specifications and recommendations
- Various hardware, standard or system-specific
- A few decades of compatibility requirements
- A tiny, bare-metal programming environment
- No huge community of developers looking at it
What can go wrong?

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- Broken CPU features (VT, NX, AES)
- Sub-optimal power management (configuration, ACPI)
- Delays and latency (SMI)
- General-purpose misbehavior (USB, performance counters)
Why might you want BITS?

- You develop a BIOS, and you want a better test criteria than “Windows boots, ship it”
- You hack OS or application code that relies on platform technologies
- You do bug triage, and want a bug reporter to check if the problem lies in their BIOS
- You want to play with hardware in a low-level way, but in a comfortable environment
“That’s why we wrote BITS”

- That’s the problem we wanted to solve
- That’s what BITS evolved into
“That’s why we wrote BITS”

- That’s the problem we wanted to solve
- That’s what BITS evolved into
- That’s not where we started
Testing reference code

- Initializes CPU power management registers
- Writes ACPI tables
- Supports frequency scaling, idling, and throttling
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- SMP, takes over CPUs
- How do you test it, without a custom BIOS?
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- DOS test harness
- 32-bit DOS extender
- Load and run the reference code
Booting an OS afterwards

- Rewrite the ACPI tables correctly
- See how the OS reacts
- Measure power consumption
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- BIOS interrupt 19H: load and boot an OS
- Read the MBR and jump to it
- Ends up back in the bootloader
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- See how the OS reacts
- Measure power consumption
- BIOS interrupt 19H: load and boot an OS
- Read the MBR and jump to it
- Ends up back in the bootloader
- No OS ever does this
- Guess how consistently it works?
GNU GRUB2

- 32-bit flat address space
- C, malloc, printf
- File input
- Command line, argument parsing
- Menu system
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- ... and it’s a bootloader
Run power-management reference code
Boot an OS
BITS on GRUB2

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- Boot an OS
- Added SMP support to GRUB (smp_call_function)
- Implemented various new GRUB commands in C
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- Boot an OS
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- Nice exploratory environment via menus and command line
BITS on GRUB2

- Run power-management reference code
- Boot an OS
- Added SMP support to GRUB (*smp_call_function*)
- Implemented various new GRUB commands in C
- Nice exploratory environment via menus and command line
- Beginnings of a test suite
Early testsuite functionality

menuentry "Power management test suite ..." {
...
  test_msr_consistency "Max non-turbo ratio" \ 
    0xCE --mask=0xff00
  test_pci "Bus master disable" \ 
    0 31 0 0xA9 --bytes=1 --shift=2 --mask=1 1
  test_msr "C1 Auto Demotion Enable" \ 
    0xe2 --shift=26 --mask=1 1
...
  test_summary
Expressiveness

- Based on GRUB2’s scripting language, “bashish”
- No real calculation besides --shift and --mask
- Shell-like conditionals: if [ $x -lt $y -a ... ]; then
- Shell-like quoting rules (magic characters, but no magic)
- All non-trivial functionality required C
- Configuration files just glued commands together into menus
C expression parsing

- Evaluate command-line arguments as a C expression
- Store results of other commands in environment

```c
cpuid32 --cpu=0 --env --quiet 1

c signature = eax "&" ~ 0xf
if c signature == 0x106a0 ; then
    set cpufamily=nhm
... 
```

- 64-bit integers only, but that’s 90% of what we needed
What about ACPI?

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- Do methods do the right thing, and return the right results?
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- Do tables contain the right data in the right structure?
- Do methods do the right thing, and return the right results?
- Hand-parsing ACPI is a bad idea
Portable implementation of ACPI
Already used by Linux and other OSes
Bytecode parser, interpreter
C API
OS-specific interface layer
ACPI

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- Ported to GRUB2 in April
ACPI testing

- Find and parse tables
- Execute methods
- Display and check results
Scripting, again

- Lack of decent scripting becoming a serious problem
- ACPI test functions written entirely in C
- No sensible way to drive from shell scripting
- Doesn’t allow exploration from the command line
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ACPI test functions written entirely in C
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Nobody other than us would ever write tests
Portal CPython 2.7 to GRUB in May
- Wrote a C/POSIX compatibility layer
- Floating-point support via “fdlibm”
- Ported much of the Python standard library
- Added “bits” and “acpi” modules
Scripting problems: solved!

- Lists, dictionaries, tuples, strings, bignums, floats
- Sorting, searching, comparisons, math
- Printing and formatting
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- Lists, dictionaries, tuples, strings, bignums, floats
- Sorting, searching, comparisons, math
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- Low-level functions in C, logic in Python
- CPU and chipset registers
- PCI
- ACPI method evaluation and value decoding
Python scripting sample

Run an ACPI method on every CPU; collect the unique values and corresponding CPUs:

```python
for cpupath in cpupaths:
    value = acpi.evaluate(cpupath + "." + method)
    uniques.setdefault(value, []).append(cpupath)
...
```
Implementing GRUB commands in Python

- We still need the GRUB command-line tools
- Useful for exploration and compatibility
- We don’t want to write them in C
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- Useful for exploration and compatibility
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- Added GRUB commands implemented via Python callbacks
- Deleted a pile of C code
Logging test results

- GRUB has no file write support
- Testsuites print results on the screen
- A record would be nice
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- Testsuites print results on the screen
- A record would be nice
- Much like a kernel panic: got a camera?
- Serial port, remote KVM...
Hammer, meet nail

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- GRUB can reserve memory so the OS doesn’t overwrite it
- Write special-case code, and read data from /dev/mem?
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- Write special-case code, and read data from `/dev/mem`?
- Linux knows how to read ACPI tables
- GRUB knows how to write them
- GRUB only provides a command-line `acpi` command
- `acpi` reads the ACPI table from a file
GRUB has devices like (hd0,0)
We added a (python) device in August
Reading (python)/foo invokes a Python callback
GRUB has devices like (hd0,0)
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Reading (python)/foo invokes a Python callback
Copy Python output to an internal log
grub>  acpi (python)/acpiolog
GRUB has devices like (hd0,0)
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Reading (python)/foo invokes a Python callback
Copy Python output to an internal log
grub> ACPI (python)/acpi/log
linux# dd if=/sys/firmware/acpi/tables/BITS bs=1 skip=36 of=bits.log
Fun with writable files

- configfile (python)/dynamic-menu.cfg
Fun with writable files

- configfile (python)/dynamic-menu.cfg
- initrd (python)/initramfs.cpio
Current status of BITS

- Framework for testing, configuration, and exploration
- ACPI method evaluation
- Python scripting in a ring 0, pre-OS environment
- Test suites in areas of our expertise
  - Power management configuration
  - P-state ratios
  - C-state residency
  - CPU configuration registers
  - SMI frequency/latency and real-time response

- Converting tests and commands to Python
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- Converting tests and commands to Python
- Used by BIOS developers before shipping boards
- BIOS problems actually get fixed!
BITS needs you!

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- What bugs have you observed?
- What do you want to make sure new BIOSes get right?
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- What platform functionality do you care about?
- What bugs have you observed?
- What do you want to make sure new BIOSes get right?
- We can help!
- Come play with low-level functionality in high-level Python
For more information

- http://biosbits.org
- Download an .iso and play
- Download the code and hack
- Drop us an email

Questions?